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SANDALWOOD SEED NURSERY AND PLANTATION TECHNOLOGY

PROCEEDINGS OF A REGIONAL WORKSHOP FOR PACIFIC ISLAND COUNTRIES

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AUSTRALIAN CENTRE FOR INTERNATIONAL AGRICULTURAL RESEARCH

AND

SOUTH PACIFIC FORESTRY DEVELOPMENT PROGRAMME

State of Knowledge Regarding Cultivation of Sandalwood

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This paper summarises the information discussed during the Nouméa workshop. It covers the technical and practical aspects of sandalwood cultivation. The aim is to provide the reader with a good overview of current knowledge concerning sandalwood silviculture and associated subjects: genetic conservation, seed storage and treatment, germination, nursery and plantation technology.

Genetic Conservation

Continuing depletion of sandalwood sites in the Pacific is detrimental to the conservation of a large genetic potential for a number of the different species. Sometimes the population is so low that persistence of the species can be endangered due to the very narrow genetic base and the low fruiting ability of the trees. Sometimes sandalwood stands are still important and managed in a sustainable manner but the characteristics for selection of trees to be logged are diameter and heartwood rate. The biggest and most valuable trees (in terms of heartwood content) will always be logged and if these characteristics (size, heartwood rate, straightness) are genetically controlled, the genetic potential of the whole stand will be lowered. As a consequence, quality of the valuable characteristics will decline.

Due to this loss of diversity several procedures are required, the main aim being conservation of biodiversity and genetic improvement *via* selection of seed batches for seedling production. Australian studies suggest genetic heritability of characteristics such as heartwood, straightness and growth rate. Progeny trials and selection of "plus trees" are therefore highly recommended for genetic improvement of the species.

In the case of an almost extinct or highly endangered population, seeds may not be available and only grafting or cutting of very juvenile branchlets is possible (shoots or suckers). These techniques, although difficult to implement, were developed with significant success rates in Fiji on *Santalum yasi*. *In vitro* tissue culture is also possible but the cost of such an operation, that must be done in a very specialised laboratory, is very expensive for island nations. For this reason, *in situ* trials should be established first in order to try to induce fruiting, particularly by control of the shade around the sandalwood trees and fertilisation.

In other cases, useful procedures include:

1. Exact identification of the local sandalwood (species, subspecies or variety...) when the identity is uncertain (Erromango - Vanuatu).

2. Selection of potential "plus trees" in the natural stands and conservation of these trees through appropriate operations. Selection criteria should include: - straightness; height and diameter dimensions; and heartwood content.

3. *In situ* agreements with land owners are desirable in order to be sure that these valuable trees will not be cut down. Attention must be focused on the fact that immediate high profit derived from the sale of a tree selected for breeding potential to a sandalwood trader will always be a risky process. Ensuring adequate conservation of the continued reproductive potential of a sandalwood stock may require keeping a sufficient population, whose size we cannot be sure about.

4. "*Ex situ*": seed collection, progeny conservation plots and progeny trials. After these progeny trials have confirmed the potential of the best candidate plus trees, these would then be used to provide stock for the creation of seed orchards.

Such a full genetic improvement programme is onerous and difficult to manage as well as being expensive. It can only be implemented in the bigger countries. However, *in situ* conservation associated with *ex situ* progeny conservation plots can be undertaken in all the islands where sandalwood is growing.

In cases of a very depleted population, or in those countries where the local species or variety is limited to a few islands, the importation of other species or varieties may lead to an ecological disaster. Introduction of "foreign" species or provenances should be avoided in the vicinity of the remaining natural stands in order to keep them pure. Such programmes are best tried where sandalwood species are absent and the objective would be to test several species in order to select the most economically suited species for the particular island.

Comments:
Introduction trials of new species/variety/provenances, should precede any large-scale planting program. For the majority of South Pacific islands three species appear to be most suitable for trials:

- *Santalum austrocaledonicum* (New Caledonia)
- *Santalum album* (India - Indonesia - seeds from Australia). The present genetic base in all the South Pacific Islands for this species is very narrow and seeds must be brought in from overseas.
- *Santalum yasi* (Fiji - Tonga, Vanuatu ?)

A fourth one should be added if seeds are available: *Santalum insulare* (Tahiti - Marquesas).

A survey of all the areas where sandalwood is believed to occur should be done. It is desirable that the range of genetic variation should be retained. We highlight the

importance of provenances of the sandalwood species. Provenances should be explored and tested in anticipated planting areas before any extended genetic improvement programme. The best provenances would merit a "plus tree" programme.

Seed Production and Conservation

Production

Local species/provenance seed is usually available but genetic quality is not always the best. *In situ* collection of seeds of reasonable quality is not always possible and protection of the best trees is difficult. An extended programme of sandalwood planting requires the creation of seed orchards where the quality (heartwood production rate, oil quality, form and growth) of the trees is known and all conditions are controlled:

- Flat and fertile sites, secured land;
- Permanent accessibility;
- Protection against: animals and humans (land tenure, fence); prevailing winds and cyclones: windbreaks, living fences; diseases and pests; birds : scaring devices;
- Possible watering during dry spells
- Large genetic base (seedlings coming from the progeny of many "plus trees" or at least potential "plus trees");
- Severe early selection on early seedling growth (assuming this mirrors heartwood and oil formation).

Seed collection

Since fruiting occurs during a long period, frequent visits to the natural stands are needed. Seed collection is best done when the fruit is ripe. For most South Pacific island species ripeness corresponds to dark red to black colour with soft flesh. Fruit with dried mesocarp must be discarded (cleaning of the seed will be very difficult and it could have been exposed to high temperatures). If seed availability is very low, seeds may be collected from the ground, provided that they are still fleshy and that they lay in the shade. Birds may eat many of the fruits, particularly during dry spells. If this is a problem then fruit may be collected less mature (bright red). Temporary scaring devices could be set on the most seed covered trees.

Depulping must be done as soon as possible: by hand in a sieve; or, mechanically with a device such as a commercial potato peeler, if large quantities are to be treated. If depulping is not done the same day, fermentation must be prevented by keeping the fruit in a cold storage area on mesh trays. For some species a flotation test is useful to separate out poor seeds that float. This test is best done immediately after depulping and before drying.

Seed storage

Seeds are completely cleaned, and soaked in a fungicide. They are then dried, out of the sun (preferably in a cool, aerated area) for 3 days prior to placing in cold storage at 3-4 ^{o}C. If a cold storage is not available, storage in a fridge is possible. In this case, drying of the seeds should be longer (10 days). Storage on sieve trays allows

respiration. Closed bags or airtight containers must be avoided. Seed lots must be well identified in order to keep track of the origin of each batch.

- Seeds are stored for at least 6 months in order to break dormancy in the case of *S. austrocaledonicum*. This break of dormancy may be species-specific and further research is required for other species.
- Seeds should not be stored for more than two years. After this period, the germination rate tends to decrease rapidly.

Comments:
In all the preceding processes, the major guidelines are :

- Clean the seeds as well as possible;

- Avoid any event which will increase the temperature of the seed: 35 - 40 °C may be lethal and exposure to sun will cause fermentation.

Seedling Production
Germination
Nursery planning must be organised in order to produce good sized seedlings for the planting period. In the majority of the South Pacific islands planting time is between December and February. As roughly, a period of 7 months is needed from the beginning of the germination phase to the planting period, it follows that the best sowing period is June-July.

One month before sowing, everything must be ready:

• Fertilisers, fungicides, soil, pots, shade-cloth, host plants and a germination trial should be planned.

• Germination media must be well disinfected with fungicide & nematicide such as Benlate, Previcur, Dithane - 78, Blilox, Ekaline, Thimet).

• Seeds are removed from the cold storage
• Seeds are nicked either by cutting the testa with a knife or by using electrical pliers
• They are soaked in cold water for 12 hours (one night) with at least one third of each seed out of the water to allow seed respiration (Figure 1) and the plate is stored in a fridge or cold storage.

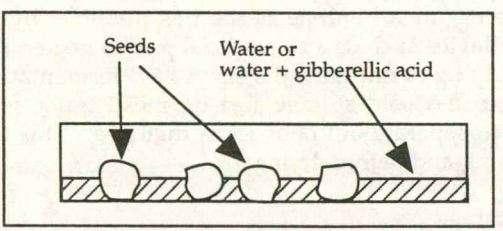


FIGURE 1. Set-up for overnight soaking of seeds.

•If gibberellic acid is available, soaking the seeds in a solution will render the germination more uniform. Final germination rate, however is not affected by this treatment.

•Gibberellic acid is diluted to the concentration of 0.1 g/l. The seeds are soaked in this solution overnight as described above for cold water soaking. The diluted gibberellic acid must be carefully stored at low temperature and well protected from light as it rapidly denatures.

•Seeds are sown on a heated germination bed made out of perlite or coarse sand in order to allow good drainage. Frequent watering by sprinklers (spray) are needed to keep the seeds humid.

•Germination temperature is kept between 28 and 32 °C.

•In the case of hotter countries heated germination beds are not required and in Indonesia direct sowing is recommended by the Forests Department. Three seeds per pot are sown and the surplus germinants are either pricked out into another pot or eliminated if they are too weak or poorly shaped.

•As soon as the first root appears (Figure 2) the germinated seeds are pricked out into a box filled with a half peat-half sand medium.

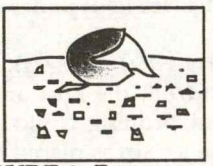


FIGURE 2. Root emerges

•As the seedling grows the hypocotyl arches. It gradually straightens up, with the seed still attached. This is the stage of development when the seedling is sufficiently advanced to be transplanted into pots (Figure 3).

•Pricking out must be carefully done in order to have the roots perfectly straight.

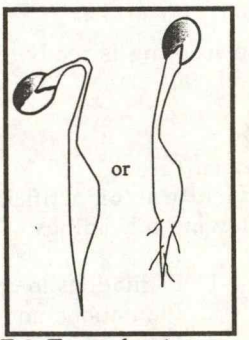


FIGURE 3. Transplanting stage

Nursery phase

Soil

Locally available loamy soils are generally suitable but require an admixture of coarse river sand. A rate of 37 % of sand seems to be optimal for both *S. album* and for *S. austrocaledonicum*. Fertilisation with 5 kg of NPK 13 - 13 - 21 per cubic metre of soil is recommended in New Caledonia. If the potting mixture is acidic (pH < 5) calcium tends to not be readily available and lime may need to be added. If the soil is too alkaline (pH > 8), it is probably desirable to add chelated iron to the mixture.

Pot

The superficial root system, specialised in parasitism, will develop best in wide pots that are preferred to narrow ones. The host plant also requires space for its roots too. The pot height should be at least 20 cm.

Host plant

One of the most efficient host plants is *Alternanthera*. First identified by CIRAD-Forêt in New Caledonia, it is now widely used as a host plant all over the Pacific. Its very ready vegetative propagation makes it most useful. The cutting is planted either on the same day (or within 10 days after) the sandalwood seedling is pricked out into the pot. However, in some cases (very sandy soil), it does not grow well and other host plants should be tried. Australian and Indonesian research has identified *Desmanthus virgatus* and *Crotalaria juncea* as very efficient host plants. In these cases where the hosts develop from seeds the host must be sown in the pot several weeks before planting of sandalwood in order to have a well developed root system.

Seedling management

- Newly pricked out seedlings are kept under shade-cloth for 2-3 weeks;

- The host plant (particularly *Alternanthera*), is trimmed regularly in order to avoid excessive competition from the host and possible drying up of the soil. However, severe or frequent pruning could be detrimental to the growth of the sandalwood seedling due to stress placed on the host plant;

- If the host plant seems to weaken, a new one must be pricked out or sown in the pot.

The seedling is ready to be transplanted after 5-6 months when it reaches a size of 25-30 cm.

Silviculture

Silviculture of artificial stands of sandalwood can be considered under the following 5 headings:

1. Plantations in open and cleared land.
2. Plantations under existing vegetation.
3. Stand improvement in shifting cultivation areas.
4. Agroforestry.
5. Home garden areas and beautification generally.

1. Plantations in Open and Cleared areas

The most common planting technique is to use open grassland or farmland. The land is cleared and worked before planting. Since all previous vegetation has been removed, it is necessary to establish field host plants. In the oldest plantations, sandalwood were planted directly and simultaneously with their final host plant.

After some years of experience, it is apparent that this design requires modification due to the various problems encountered. These include the observation that sandalwood takes a long time to parasitise host plant roots, and sometimes does not do so. Similarly, protection from wind does not become effective until some years after host planting, or should the host plant be too close, it soon interferes competitively with growth of the sandalwood. For these several reasons, it is now recommended that intermediate host plants are used. This procedure will allow the sandalwood to be supported in its early growth until it is able to successfully parasitise the final host.

Soil selection

Sandalwood can grow on a very broad range of soils but for a high success rate, several points should be taken into account :

- permanently wet soil or occasionally flooded areas must be avoided;
- areas on steep slopes, particularly if they are exposed to wind must be avoided due to the water shortage that will occur.
- alkaline soils generally give better success than acidic soils.

Site preparation.

Site preparation should aim to provide:

• Conditions for perfect propagation of the root systems. On flat land crossed ripping and ploughing is done; on slopes (> 3%), ripping is done along the contours.

• Protection against animals and sometimes humans; provision of fences against cattle and goats; windbreaks established 2 to 3 years before sandalwood planting; and cleared breaks to prevent fire encroachment.

• Elimination of the existing vegetation. If climbing vines are present on the land, chemical action should be considered in order to eliminate them as well as possible, for example systemic herbicides (such as Round-Up) or anti-germination herbicides.

Caution :

Herbicides, particularly the systemic ones, must be avoided once the sandalwood has been planted because of its parasitic habit. At present we have no definite indication of host-parasite transfer.

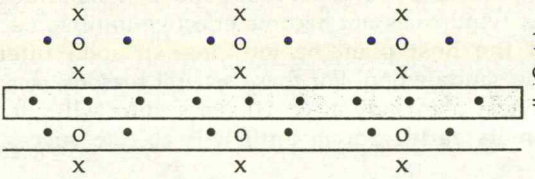
Layout

Two kinds of layout can be considered.

(a). Pure lines (Figure 4)

The placing of intermediate hosts between the main rows of sandalwood is not possible if mechanical weeding is planned. If hand weeding is to be done, then intermediate hosts can cover the soil faster and protect the sandalwood trees from weed competition. Alternatively a ground creeper may be planted between lines in order to cover the soil. The rate of at least one host per sandalwood must be respected.

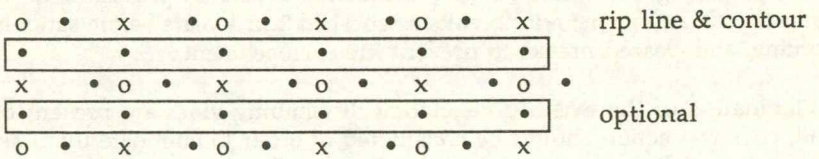
FIGURE 4. Possible arrangement of sandalwoods and hosts (x = final host; • = intermediate host; o = sandalwood).



In this procedure, the lines are oriented across the main wind direction. This layout is mainly recommended in flat areas. The planting of several intermediate hosts per sandalwood will increase the nutrient and water demand. Fertilisation is recommended at the beginning and, in dry areas, supplementary watering should be considered.

(b). Alternating lines (Figure 5)
This pattern is particularly recommended when the soil is ripped in one direction only. That direction will then be the preferred direction for the roots. However, it will hinder cross propagation of roots at the start. The intermediate host will also be established along the line on each side of the sandalwood.

FIGURE 5. Alternating line arrangement of sandalwoods and hosts (x = final host; • = intermediate host; o = sandalwood).



This technique is recommended for both slopes and flat areas. Spacing and stocking still have to be investigated in order to maximise the economical return of such plantation layouts.

Fertilisation

• Fertilisation is recommended particularly during the first years of the growth. Since the density of plants is high (sandalwood, host plant, intermediate host...) and a strong height growth is essential for a straight bole, the need of nutrients is high.

• When the sandalwood has a sufficiently long bole and the final host plant is parasitised, fertilisation should not be needed any more.

• Fertilisers used should be poor in nitrogen (in order to avoid any problem to host plants when they are nitrogen fixing trees), but with the usual P, K content and rich in Ca.

• In soils deficient in Ca, consideration should be given to supplying a Ca input (*e. g.* fine crushed coral).

Planting : (See also timing)
Sandalwood seedlings are planted with their nursery pot host plant. The polybag is cut at 1 cm from the base and then removed. The soil is well packed around and the collar of the seedling must be exactly at the surface of the ground. For very special planting (orchards) *Alternanthera* (plants or cuttings) can be established right beside the sandalwood.

Maintenance

(a). Weeding

- Weeding methods depend on the types of weed present. Weeds as well as planted hosts will be parasitised and too much weeding is detrimental to sandalwood growth. However, weeds are in competition for mineral nutrients and may provide an undesirable hazard in areas with fire risks.
- Climbers and vines are detrimental to plantations and prior elimination by chemical herbicides should be envisaged.
- The shade of the host plant will also control the weeds. Planting of host plants one or two years before the sandalwood will reduce the density of the weeds when sandalwood is transplanted.
- Intercropping during the first years has been done in some areas. Cultivation of crops provides another way to keep the soil clear of weeds. The most useful system would be to plant some species that cover the soil very well without climbing (pumpkins, glycines). Intercropping is not to be recommended however, as there is considerable potential for damage to sandalwood plants.

(b). Pruning

- Concentration of the heartwood on one single and straight bole will ensure a higher rate of heartwood production and highest value wood yield.

- When sandalwood is growing in sound conditions without moisture stress, its bole shape is generally straight and natural pruning occurs. If the conditions are less good or if drought spells occur, the trees can make forks and then produce several leaders (broom shaped). In this case, pruning (in the sense of giving a shape to the tree) must be done. It aims to produce a single bole, as straight as possible with a high stem ratio (Figure 6).

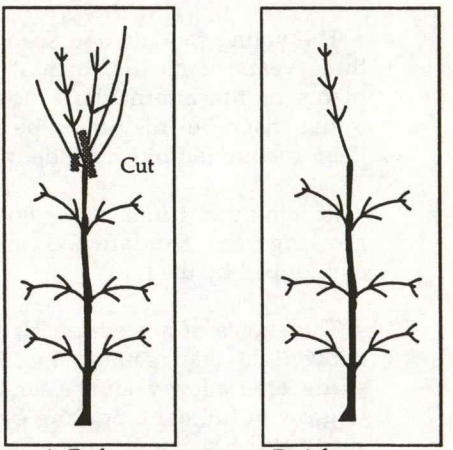


FIGURE 6. Before and after pruning.

- A good pruning insures ventilation around the boles. It will lower the possibility of disease or pest attacks. A post-pruning sealant must be used to minimise the potential for disease.

- Since sandalwood has a vigorous shooting ability, a strong pruning will induce epicormic shoots. In order to avoid this problem, only the potential leaders should be cut and all the branches kept on the bole. This will ensure a sufficient crown. These branches can be cut a few years later (if needed), once the crown is strong enough again.

- Pruning must be done with proper pruning saws (well disinfected with fungicide) or with strong secateurs, by skilled workers, in order to avoid wounds on the bark.

(c). Beating up

After one year, the plantation is beaten up in order to ensure sufficient stocking for the future stand.

(d). Disease and pest control

A number of leaf damaging pests may be at least partially controlled through the use of particular host plants known to be repellent to insects (such as *Melia azedarach, Azadirachta indica* or Neem). These are also efficient host plants. Pest attack will occur mainly on soils which are not suited for sandalwood *e.g.*: too wet, too poor.

Phytosanitary regulations must be observed and enforced to avoid the introduction of **Spike disease** which causes huge losses to *S. album* in India. This disease is not only carried by sandalwood but by many other plants. Plants should not be imported from Spike disease infected areas.

Host plant management

The host plant has several roles: parasitism, protection, shade.

• The young sandalwood seedling grows better in light shade for the first three years of its life, then it thrives in almost full light. The final host plants or the intermediate host plants planted earlier, can provide such initial shade but they must be strongly controlled later in order to prevent them casting too much shade over the sandalwood.

• Pruning and trimming of host trees may be required if the host is a fast growing tree. Sandalwood must always have lateral shade but not be overtopped by the host.

• The choice of a medium sized (1-2 m high) intermediate host plant can allow light management too. The intermediate host provides the initial shade: after a few years the sandalwood will be taller than it, and then is able to grow in full light. Spacing of hosts is best planned to provide little lateral shade at the beginning, and then more later on.

Timing

Planting must be done at the beginning of the rainy season. Therefore, germination must be planned 6 to 7 months ahead (Figure 7).

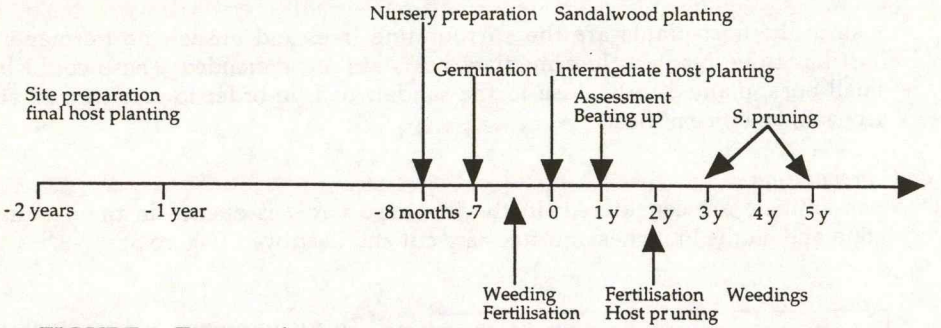


FIGURE 7. Timing of operations for planting in open or cleared areas.

Assessment

Data should be collected (girth [or diameter] / height / heartwood diameter / form / merchantable height) in order to assess stand evolution and to provide for appropriate silvicultural recommendations.

Thinning

Thinning aims to control competition between trees for sunlight and for nutrients. In the case of sandalwood, the initial spacing is wide : 6 m x 3 m (giving 555 trees per ha), but the host plants will strongly compete for nutrients. For that reason, thinning aims mainly to discard sick trees, slow growers or badly shaped individuals. The control of competition will be more efficient through control of host plants by trimming, or pruning. However, if stocking is too high, elimination of some of the planted trees will be necessary. Present knowledge of silviculture does not allow us to give firm recommendations for either initial stocking or thinning. A reasonable aim would be for 400 stems ha^{-1} at 5-10 years and 300 stems ha^{-1} at 15-20 years, but considerable research is needed to predict desirable stocking and consequential spacing.

2. Plantations Under Existing Vegetation

This mode of management is the major one to be considered in many cases, particularly in small plots directly managed by the landowners. The techniques for formal plantations in open areas need a high level of management for stand establishment and considerable maintenance, often beyond the capacity of small holders. Planting under natural vegetation only requires operations that the landowner can provide by himself. For example, weed control is less intensive than in open plantations.

Site

The technique is suitable for areas of secondary forest or bush only a few metres high. The existing vegetation will provide the permanent hosts for sandalwood.

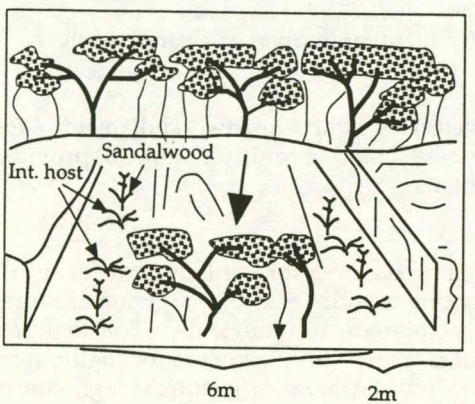
Layout and spacing

- spacing between rows will be wider than spacing in the row in order to minimise the cost for a given stocking. A spacing of 6 m between the rows seems to be suitable with a spacing of 3 m in the row.

- since the host plants are the surrounding trees and bushes, no permanent host has to be planted. Intermediate hosts are recommended. These could be small ones, planted very close to the sandalwood, in order to give immediate access to an efficient host.

Land preparation

Two possibilities are considered: In the first case a row is opened in the existing vegetation and all the branches and trees are cut and destroyed (Figure 8).



This is recommended for bushy vegetation : *e. g. Leucaena* thickets.

- width of cleared strip: 1.50 m - 2 m

- the direction of the strip is chosen across the prevailing winds in order to protect the sandalwood as well as possible;

- holes are dug every 3 metres in the row.

FIGURE 8. Row opening in bush.

Other designs, similar to this one can also be effective. For example, on the upraised coral of a small island, where the vegetation is composed of tall *Casuarina* and a low bush of species such as *Pisonia grandis, Pandanus,* and *Guetardia;* all the *Casuarina* may be kept alive (they provide a light shade as well as a protection against wind and see sprays) and rows are opened in the bush. The seedlings are efficiently protected and there is enough final host for them.

In the second case, the existing trees are killed by ring barking and poisoning and only the lower vegetation is removed in the row (Figure 9). Ring barking is done several months before planting. This technique is recommended when vegetation is low and mainly composed of spreading trees.

Total destruction of the canopy could open a large area that would then be susceptible to wind damage: *e. g.* secondary forest of *Acacia spirorbis.*

The dead trees will hold the stand together and wind damage due to the fall of trees is unlikely.

- width of the strip where all trees and branches are ring barked : about 2 m;

- the direction of the rows is less important than for the previous system but it is always recommended to choose it across the prevailing winds;

- holes are dug every 3 metres in the row.

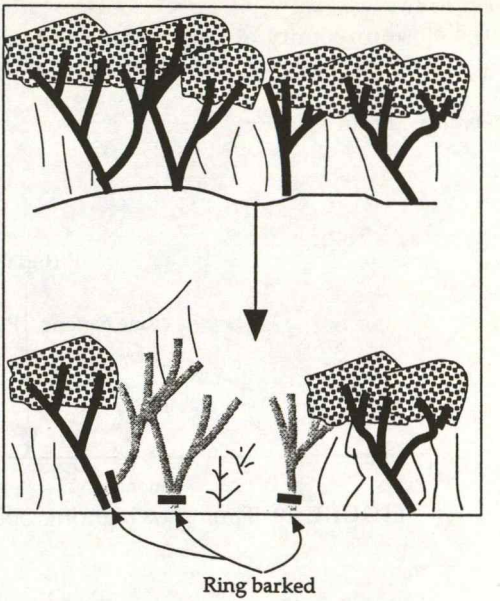


FIGURE 9. Opening by ring-barking.

Fertilisation
In New Caledonia, slow release or complete NPK + Ca fertiliser is mixed with the soil in the bottom of the hole (80 to 100 g) before planting.

Planting
Planting is best done at the beginning of the rainy season. This allows some flexibility in timing of planting due to the high protection given by the surrounding vegetation. Planting in the wet season results in lower transpiration rates of the seedlings.

Weeding - Maintenance
The shade of the surrounding vegetation will provide some control of weeds but some weeding is still necessary.

- Annual pruning and trimming of the surrounding vegetation is recommended in order to prevent it from overtopping the sandalwood.

- After some years, should dead trees disturb the growth of the sandalwood, the dead tree branches must be cut in order to avoid poor form on the sandalwood.

- After 4-5 years, a vigorous trimming of the surrounding vegetation will be necessary to provide more light for the sandalwood crown.

Pruning
The close proximity of surrounding vegetation will enable the sandalwood to grow quite straight and fast at the beginning and pruning should not be necessary.

Timing (Figure 10)

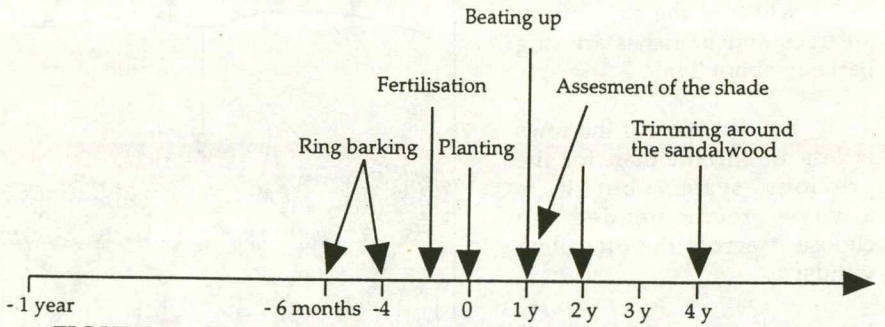


FIGURE 10. Timing of planting operations into existing vegetation.

3. Improved Stands in Shifting Cultivation Areas.
On islands where shifting cultivation in used with long periods of rotation, this system is feasible. Two possibilities can be used depending on seed availability.

Seeds are available in quantity.

- The farmer collects the ripe fruits.

- When the bush is slashed and the branches dry enough to be burned, the whole fruits are thrown over all the area, then the branches are burned.

- It is preferable that some small trees are kept in order to provide host plants. If there are some *Melia* sp. or legume trees, they should be preserved.

- The young seedlings will develop while the cleared land is being used for gardening as the farmer will preserve them during his tending of the garden.

- Once the garden is abandoned, the sandalwood seedlings will grow by themselves.

- If the field is left without any care the sandalwood seedlings will be in very strong competition with the other trees and few of them will survive. However, numbers are likely to be sufficiently high to give a valuable stand.

- The owner can also come back every 1 or 2 years and weed around the sandalwood seedlings. Results can be surprising with thousands of trees per hectare.

• If the farmer wishes to cultivate this plot again after 10 - 12 years, he must preserve the sandalwood and some host trees, and he has to protect the sandalwood from fire. The slash and burn technique must be modified otherwise few of the sandalwood will survive the fire.

• Thinning and pruning should be done 2 years before re-cultivation of the garden.

• Since sandalwood stocking can be high and the trees surrounded by dense vegetation, the trees are tall and thin with small crowns. Complete removal of the surrounding vegetation along with thinning will make the stand particularly fragile in countries where cyclones or strong winds occur. Providing thinning is done 2 years before re-cultivation, the sandalwood will get stronger and would be less subject to wind damage when the major part of the vegetation is removed for gardening.

Seeds are scarce or unavailable

• In this case, seedlings are grown in a nursery and after the field is burned for gardening purposes, they are planted among the crops.

• It is better to plant them in straight rows in order to find them easily during future weeding.

• This technique needs more care since the initial stocking is low. Weeding must be done at least twice in the first year after the garden is abandoned and then annually until the sandalwoods overtop the weeds.

These two systems are well adapted for areas where shifting cultivation is still used particularly the first one because natural seedlings can colonise rocky areas where planting is almost impossible and gardening very difficult.

For this operation, as well as for any other, the first stage would be to plant seedlings around houses in fertile areas in order to produce fruit as fast as possible.
Once the fruit/seeds are available in large quantities, the previous techniques can be carried out easily.

4. Agroforestry

This section is concerned with those areas where crops are cultivated regularly with a short fallow period. Sandalwood is not a major target of the system, but it is complementary. It will be incorporated along with other tree crops used by the people.

Sandalwood needs a permanent parasitic link with its hosts and this link is provided by its superficial root system:

Alley cropping systems

- If the soil is ploughed all around the trees, then the superficial root system and existing parasitic links will be destroyed. The only system to be envisaged in the case of annual crops is an alley cropping where sandalwood is integrated among the other trees of the alley, which provide the permanent hosts. An unploughed band of 0.50 to 1 m on each side of the trees must be preserved. It allows the development of the trees' root system. At the same time, the grass on it protects the soil against erosion. The band is set along the contours.

- Sandalwood can be associated with any kind of living fence with bushes or trees.

In orchards or in plantations

For example, sandalwood may be grown with cacao, coffee and fruit trees of various types.

- In an intensive plantation where productivity must be at a maximum, it is not recommended to plant sandalwood. The parasitic link might lower production and it will disturb the design of the plantation.

- However, in examples of extensive production, as is often the case in the villages, optimum production is not the target and possible diminution of fruit production will not be detrimental. Planting of sandalwood is an option. The stocking must be low.

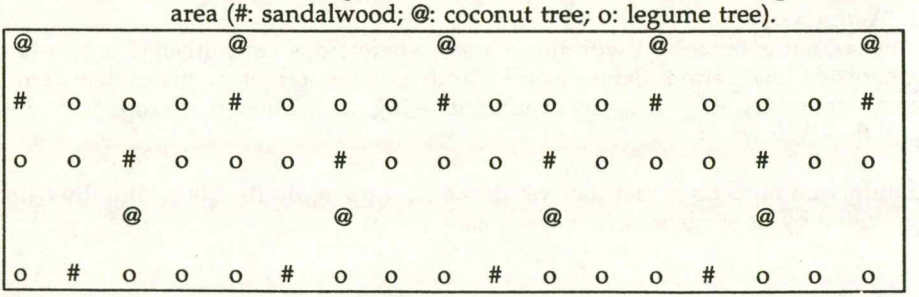
Coconut plantation

Sandalwood and legumes could be planted in rows between coconut trees as in Figure 11.

- In intensive conditions, sandalwood is not recommended.

- In more extensive cultivation, frequently found in the South Pacific, sandalwood could be associated with a legume under coconut trees. The legume will be the host plant and at the same time will improve soil fertility. Later on, once the sandalwood is tall enough, livestock can be added to this system.

FIGURE 11. Possible arrangement of sandalwoods in a coconut plantation area (#: sandalwood; @: coconut tree; o: legume tree).



Sandalwood can be associated with other trees in living fences or boundary fodder trees, but in this case, it must be protected against cattle or goats. The sandalwood will be out of danger once the base of the crown is higher than livestock can reach and the bark is strong enough to support skin rubbing of cattle.

This system requires protection of the sandalwood until it is out of danger from browsing. This is quite difficult and costly. Such a stock and tree association is difficult to manage and needs a lot of care.

5. Proximity Gardening and Beautification

Sandalwood should be planted around houses or in back yards. If people are aware of its value they will tend it. It will produce fruit that can be used for field propagation. There is always land available for this kind of home use. For example in Ile des Pins, the highest stocking rate and volumes of sandalwood are inside the village of Vao. In this case, land ownership is not in dispute. This is not always the case in the bush.